MAPPING OLIVINE BASALTS USING NEAR-IR MULTISPECTRAL IMAGING.

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In a series of publications [1,2,3] Pieters and co-workers identified mare basalt units on the Moon with a unique combination of spectral characteristics using near-IR spectra of individual locations within maria. The units, occurring in western Imbrium and near the crater Flamsteed and designated HDSA and hDSA in the notation of Pieters, 1978, were interpreted as being relatively high in titanium, and exhibited the peculiar characteristic of having a weaker 2-micron pyroxene band than 1-micron pyroxene band. This latter characteristic was attributed to several possibilities, but most likely to us was the interpretation that these mare basalts contain abundant olivine. Olivine is present in varying amounts in basalts and has no 2 micron band, but exhibits a strong 1 micron band. Invoking abundant olivine seems the simplest explanation for the spectral characteristics of these basalts.

Observations

Using Galileo visible and very near IR multispectral imaging with groundbased near-IR multispectral imaging described elsewhere in this volume [4], we have mapped the distribution of these olivine-rich units on the basis of the relative depth of the one and two micron bands. This technique is the same as used previously for spot spectra [5], but applied to a hemispheric data set (Fig. 1). The boundaries of these units are similar, but not identical to those mapped by Pieters and coworkers. Lacking continuous near-IR imaging data, these workers defined the unit boundaries principally on the basis of uv-visible ratio unit boundaries. Our data suggest that there is a close, but not 1:1 correspondence between the near-IR and UV-vis anomalies, suggesting that there are a range of basalt types with varying olivine and titanium contents.

The western Imbrium exposures of these units have 2 micron band depths approximately 1/2 the 1 micron band depths. If, as we have suggested elsewhere in this volume, the mafic band depths are dictated by the total FeO in mafic minerals, then it follows that the olivine/pyroxene ratio of these units is approximately 1:1, because the entire 2-micron band is attributable to FeO in pyroxene and it has half the depth of the 1 micron band, which is due both to olivine and pyroxene. The HDSA unit near Flamsteed similarly has a roughly 1:1 ratio of olivine/pyroxene. However, these units vary in FeO and TiO_2 contents (Table 1; derived using the calibrations described by

Blewett et al [6]); compositions of the Imbrium flows were also described by Friedman et al. [7]. The two igneous complexes contain higher FeO than the typical mare flow, which tend to have 15 to 17 wt.% FeO [8].

Implications

Olivine basalts occur in the Apollo collections, with well-studied suites in Apollo 12, 15, and 17 (see [9] for references). Apollo 12 olivine basalts are richest in olivine, with an olivine/pyroxene ratio of almost 0.4. None of the Apollo samples approaches a ratio of 1. Even the picritic glasses [10] have normative olivine/pyroxene ratios of much less than 1; the highest values are about 0.65, probably within error of our estimate of the olivine/pyroxene ratio in Flamsteed and Imbrium. This raises the possibility that the prominent olivine basalt flows in these maria are compositionally similar to picritic volcanic glasses, or close derivatives from such a magma type. This is important because Longhi [11,12] has shown that few if any mare basalts are related to picritic glasses among lunar samples. This is surprising because the magmas like those represented by the picritic glasses would readily fractionate olivine (and eventually ilmenite in the high-Ti cases), producing an array of derivative magmas. If no such products exist, it suggests that the picritic magmas erupted completely, or at least did not stall in magma chambers. It is also possible that there are lava flows with compositions like the picritic glasses, perhaps eruptive products after volatiles were exhausted and explosive volcanism stopped.

Table 1. Units mapped by [2]; data from [8].

Unit	Type Location	FeO (wt%)	TiO_2 (wt%)
HDSA	Flamsteen	20	10
hDSA	Imbrium	18	5

Allowing the possibility of a link between some picritic glasses and mare basalts, we can explore the possible links for the olivine basalts in western Imbrium and near Flamsteed. The high FeO contents of these olivine basalts is consistent with such a link, as the picritic glasses tend to have somewhat higher FeO than the mare basalts. The Flamsteed flows contain 10 wt.% TiO_2, similar to TiO_2 in Apollo 11 orange glasses [10]. The Flamsteed flows could also be related to other high-Ti pyroclastics by fractional crys-

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tallization, such as the Apollo 17 yellow glasses [10], which contain 6.9 TiO_2, but would fractionate to higher values. Depending on how much fractional crystallization took place, the Imbrium flows could be related to the Apollo 14 or 15 yellow glasses [10], which contain 4.6 and 3.5 wt.% TiO_2, respectively, or to the Apollo 17 yellow glasses. Regions of exceptionally high TiO_2 in Mare Tranquilitatis might also be related to primitive picritic magmas [8].

Whether related to picritic magmas or not, these high-FeO, medium to high TiO_2 lavas probably formed by relatively high percentages of partial melting of mantle sources that contained olivine, pyroxene (probably both augite and orthopyroxene), and ilmen-

ite, but as Longhi [e.g., 11] has pointed out, the origin of mare magmas may have involved complex processes such as polybaric melting. It is interesting that the olivine basalts described here form distinct petrologic provinces. The magmatic activity in western Imbrium took place in at least three main pulses over a period of about 500 My [13], implying that conditions for the formation of these basalts in the mantle were relatively constant for at least that long. This places some constraints on the dynamics of the lunar mantle, especially if the genesis of the magmas involved polybaric melting.
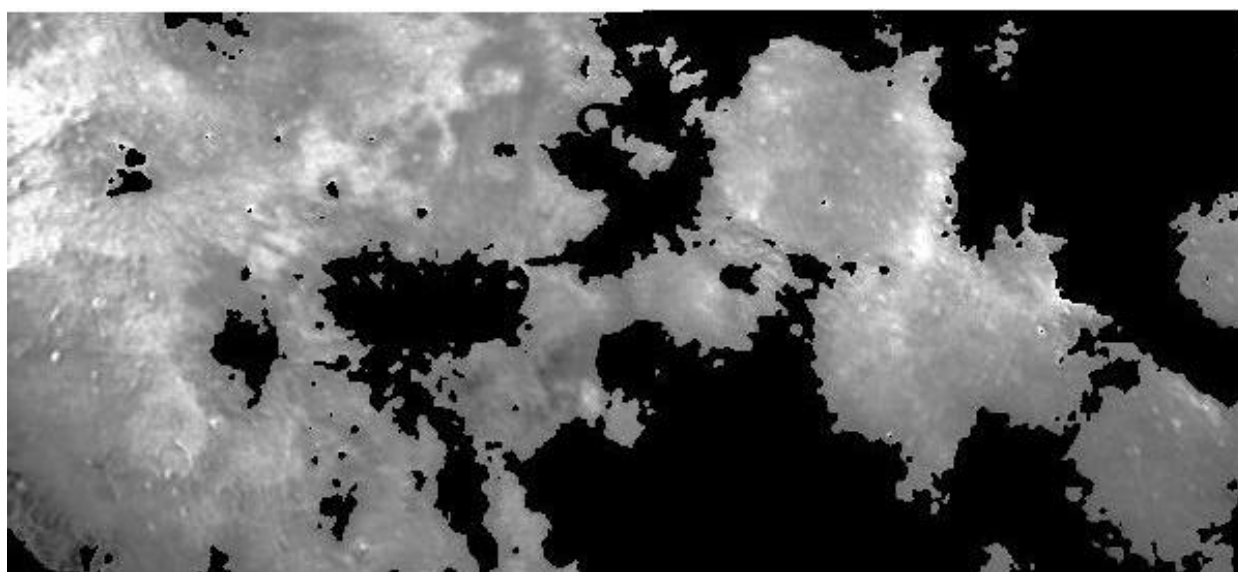

Figure 1. 2 μm band depth normalized to 1 μm band depth. This corresponds roughly to olivine distribution in nearside mare. Latitude limits are +40 to -15, longitude limits are +60 to -60.

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